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(54) Well tools

(57) Well tools for running and setting a well safety valve 150 include a lock mandrel M for releasably locking the valve at a no-go landing nipple in a well bore and a running tool R for running and setting the lock mandrel M. The lock mandrel M includes a body 30 provided with a no-go ring 45, locking dogs 32 on the body, and an expander sleeve 33 movable upwardly in the body 30 for expanding and locking the dogs 32. The running tool R includes a tubular core 135 having an end 138 engageable with an operating tube 151 of the safety valve, an upper latch key assembly 102 for engaging the lock mandrel housing 30 to couple the running tool R on the lock mandrel M, a lower collet assembly 133 for operating the expander sleeve 33 of the lock mandrel M to expand the locking dogs 32, and a head for connecting the

((57) continued overleaf)

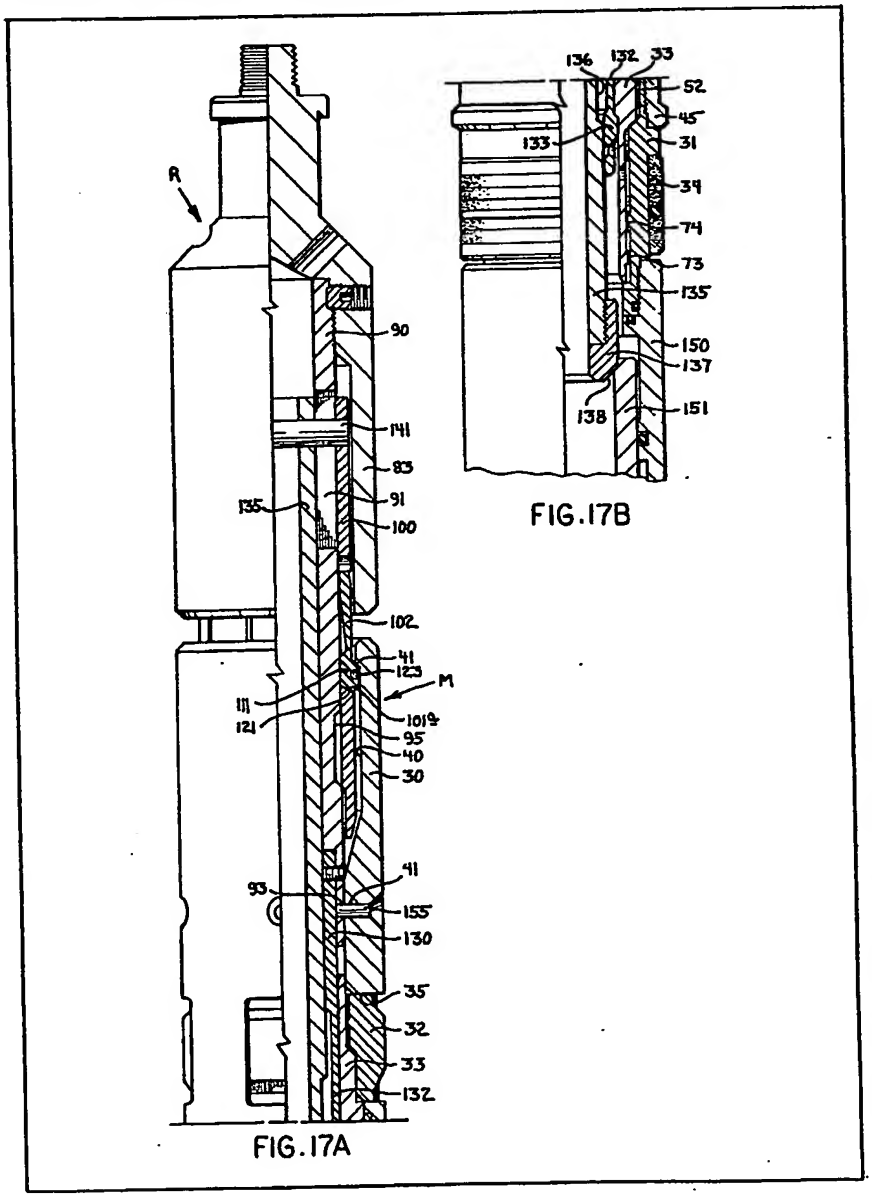

FIG.17A

FIG.17B

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running tool in a wireline tool string. The running tool R has locking features which apply a force from a spring of the safety valve to the latch keys to lock the running tool in the lock mandrel. A safety valve is connected on the lock mandrel which is coupled on the running tool. The assembly is lowered in a well to a no-go nipple. A control fluid pressure to the safety valve relieves the spring force from the running tool core 135 and the running tool is pulled upwardly expanding the lock mandrel dogs 32 and releasing the running tool from the lock mandrel.

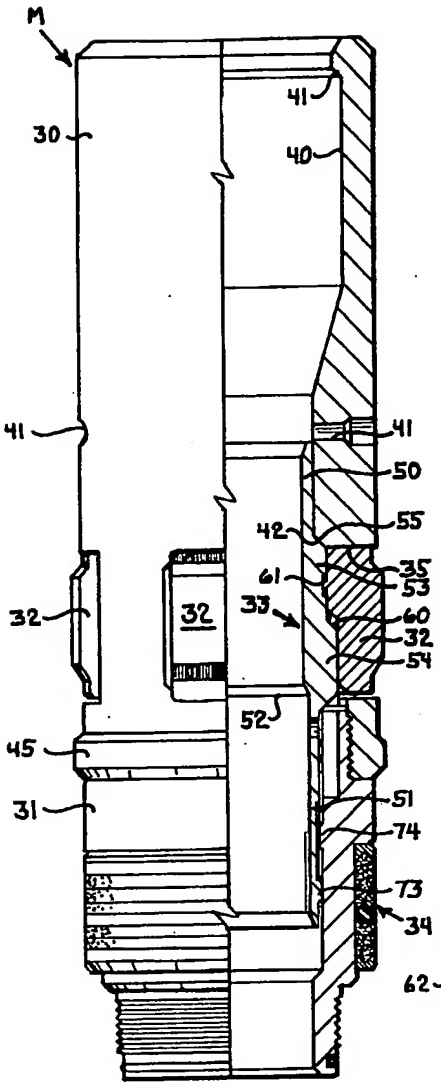

FIG. 1

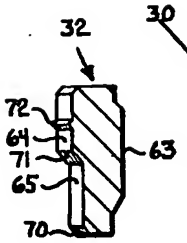

FIG. 4

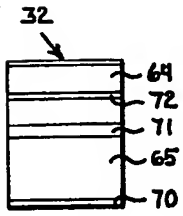

FIG. 5

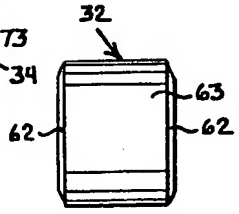

FIG. 6

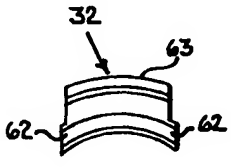

FIG. 7

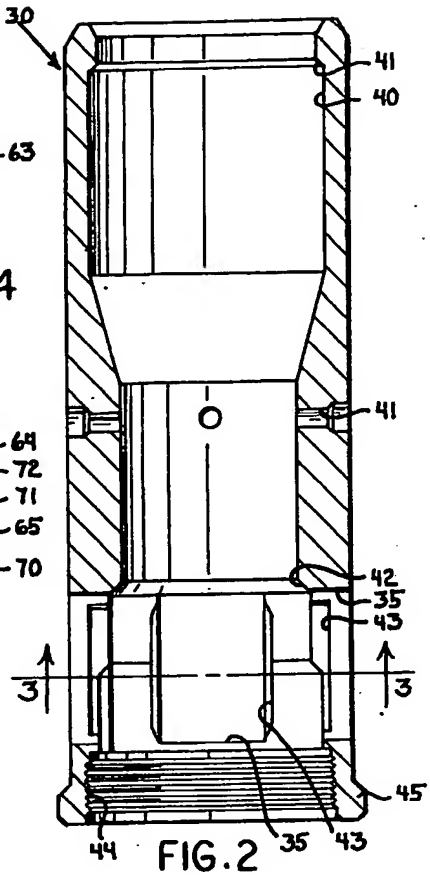

FIG. 2

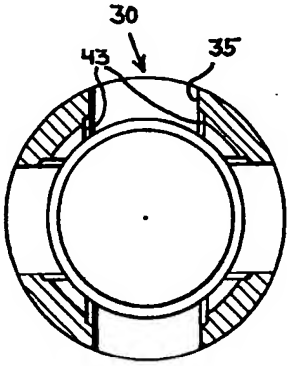

FIG. 3

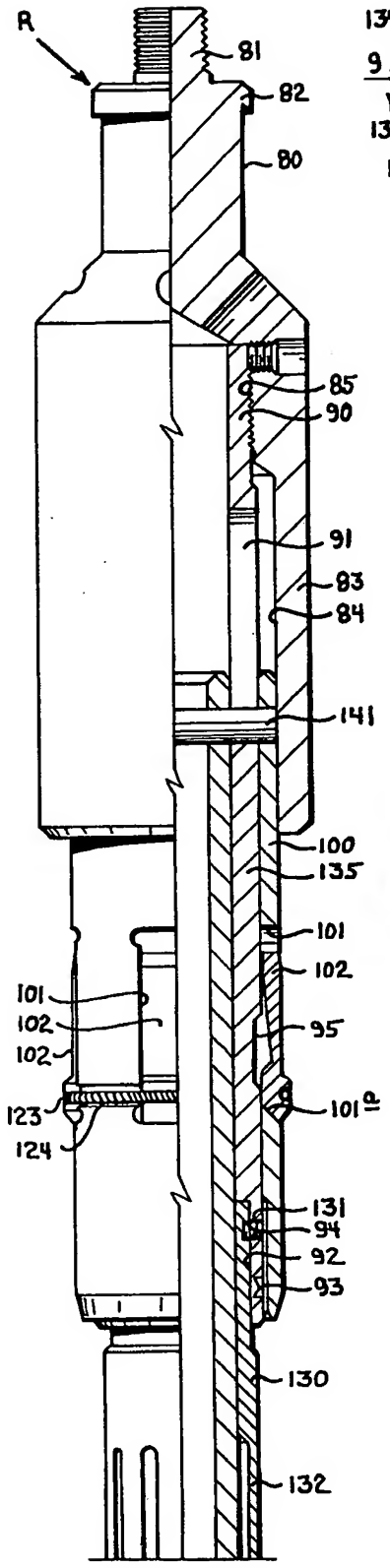

FIG. 8A

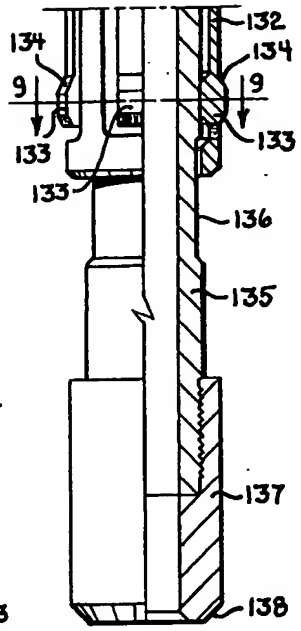

FIG. 8B

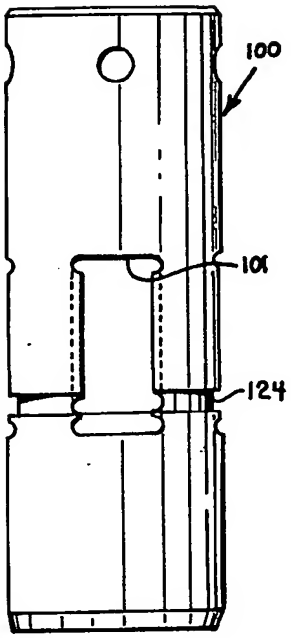

FIG. 10

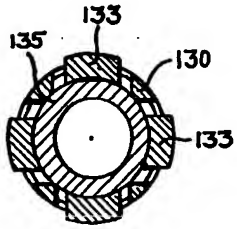

FIG. 9

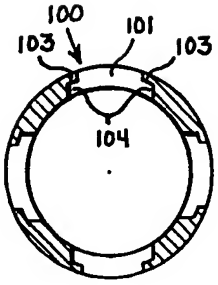

FIG. 12

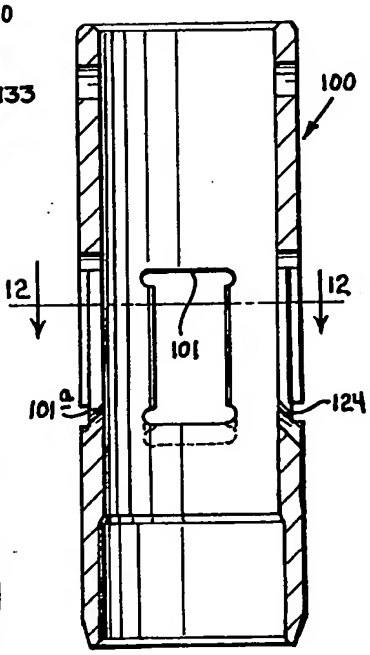

FIG. 11

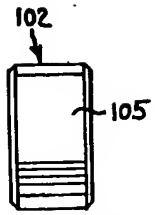

FIG. 13

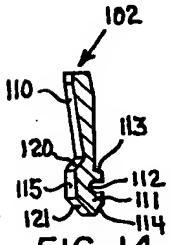

FIG. 14

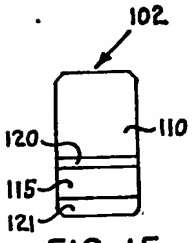

FIG. 15

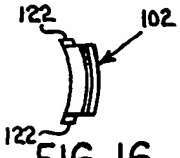

FIG. 16

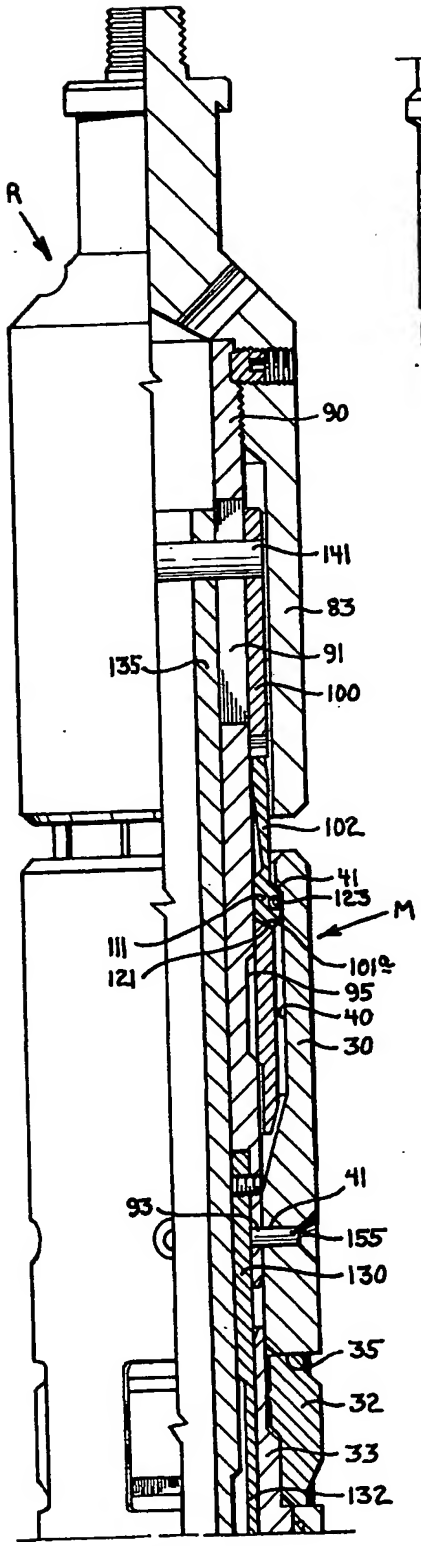

FIG. 17A

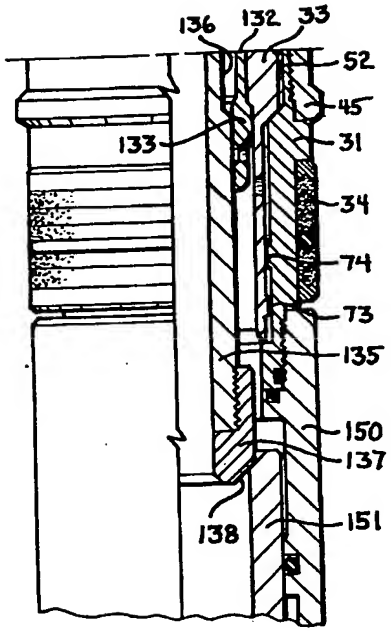

FIG. 17B

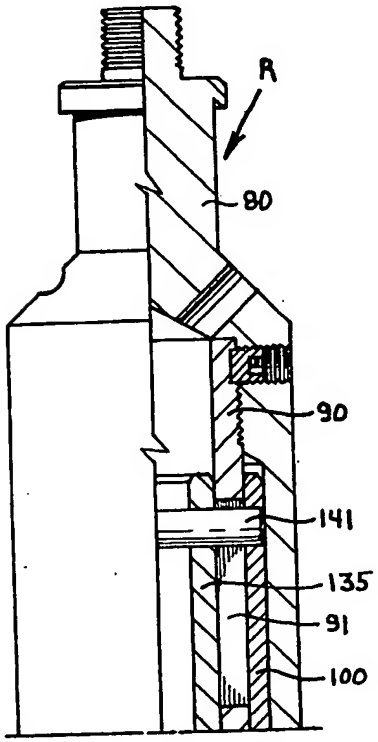

FIG. 18A

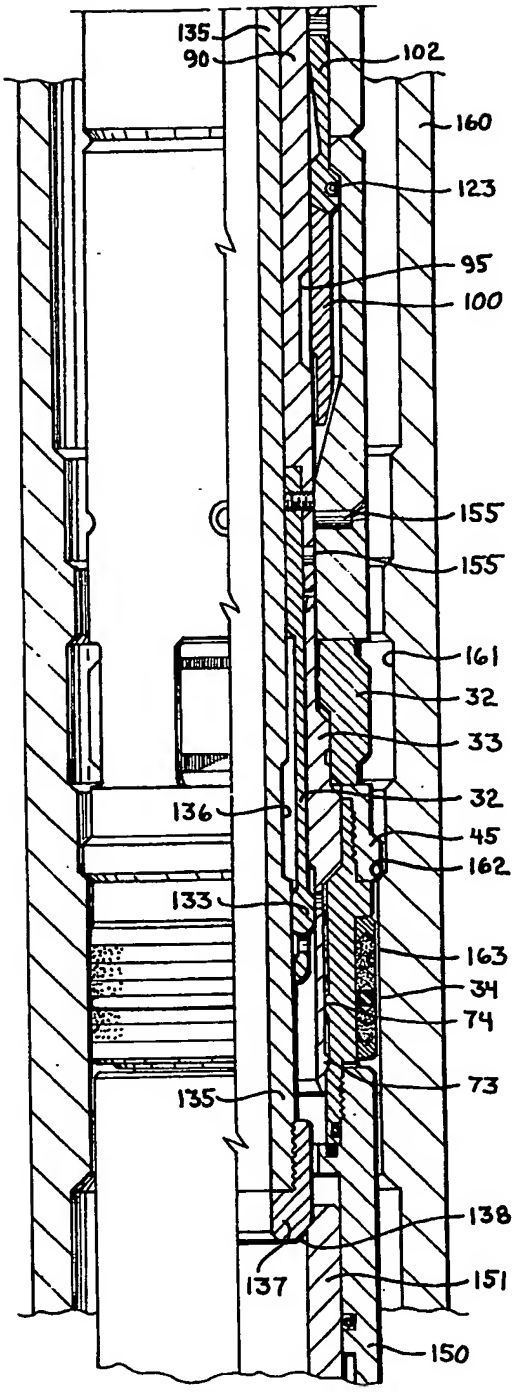

FIG. 18B

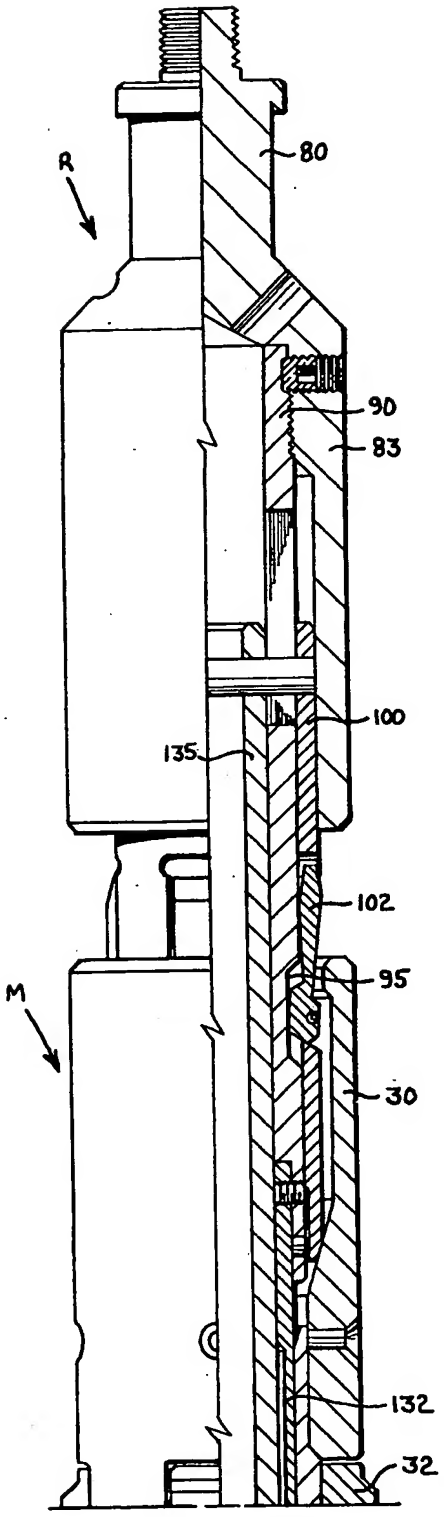

FIG. 19A

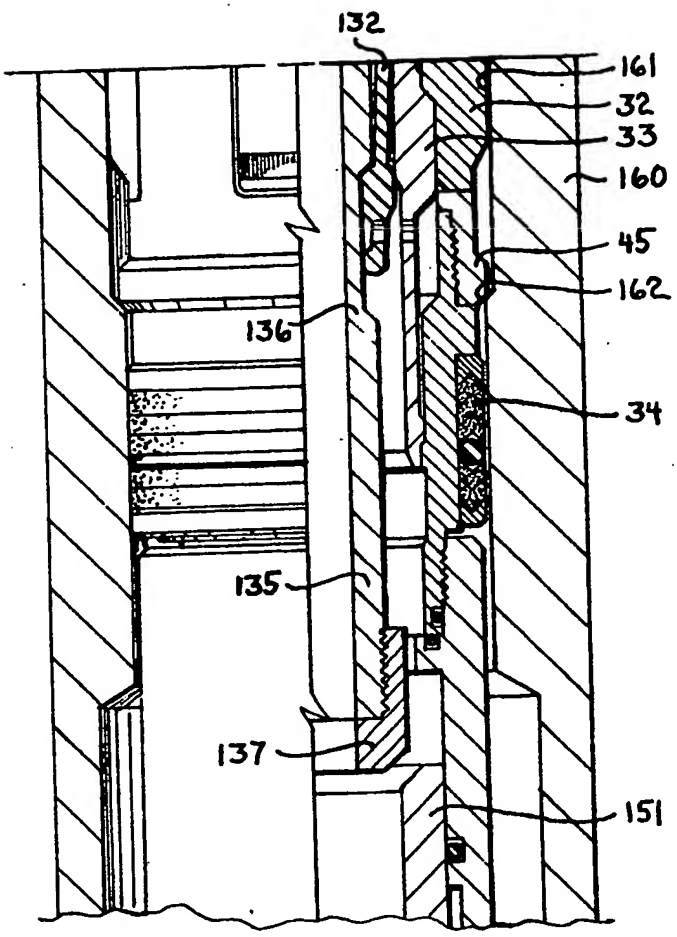

FIG.19B

SPECIFICATION
Well tools

This invention relates to well tools and more particularly relates to a lock mandrel and running tool for releasably locking a flow control device such as a safety valve in a flow conductor of a well.

In the well art, particularly that relating to oil and gas wells, it is standard practice to complete the wells using wireline equipment and methods which provides for substantial cost reductions during future well servicing operations. Wireline completion methods and equipment are illustrated and described in substantial detail in PETROLEUM ENGINEER INTERNATIONAL for August 1981 at pages 83—89. Presently available lock mandrels for sub-surface safety valves are of the extension hanger type which may present several operational problems when used with safety valves. Extension hanger locks are set by applying force in the same downward direction required for driving the safety valve into the landing nipple in which the valve is to be locked. The friction caused by packing between the safety valve and the landing nipple may require such excessive drive-down force that the lock mandrel is prematurely set. Further, it is possible to only partly engage the lock mandrel in the recess, establish control line pressure, and remove the running tool used to set the lock mandrel without any indication of a serious problem. One remedy which has been employed is a spring isolator device which eliminates major problems but still may malfunction. The locking sleeve of the extension hanger type lock must move in the opposite direction from flow to lock a safety valve. It is possible that flow could lift the locking sleeve releasing the lock.

It is, therefore, a particularly important object of the invention to provide a new and improved well tool.

It is another particularly important object of the invention to provide a new and improved lock mandrel for use in wells to releasably lock devices such as safety valves at a landing nipple along the flow conductor of the well.

It is another object of the invention to provide a lock mandrel operable with wireline equipment.

It is another object of the invention to provide a lock mandrel which is set by a force applied in a direction opposite to the direction of force required to drive the device such as a safety valve connected with the lock mandrel into the landing nipple in which the lock mandrel is set.

It is another object of the invention to provide a lock mandrel which may be driven downwardly with unlimited force without the possibility of pre-setting the lock.

It is a further object of the invention to provide a lock mandrel having a locking sleeve which moves to lock the mandrel in the direction of flow in the well thereby preventing well flow from releasing the lock.

It is a still further object of the invention to provide a lock mandrel which requires that the running tool be released from the lock mandrel and the safety valve connected with the lock mandrel be properly set in the landing nipple before the running tool can be released.

It is another object of the invention that safety valve control line integrity be established before the running tool can be released from the lock mandrel.

In accordance with the invention there are provided a lock mandrel for releasably locking a well device at a landing nipple in a flow conductor and a running tool for running and setting the lock mandrel. The lock mandrel includes a tubular body having circumferentially spaced windows, a locking key supported in each of the windows for radial movement between lock and release positions, and a key expander sleeve movable within the body behind the keys for expanding and locking the keys outwardly. The running tool includes a fishing neck for supporting the tool in a well, a retainer dog assembly telescoped into the fish neck including dogs for releasably engaging the lock mandrel body, a setting sleeve collet assembly telescoped into the retainer dog assembly for releasably engaging the expander sleeve of the lock mandrel, and an operating prong telescoped into the setting collet assembly for engaging the operating tube of a safety valve connected with the lock mandrel to hold the safety valve open while running the lock mandrel and valve. The prong assembly is coupled with the retainer dogs to apply a holding force to the dogs when the running tool is coupled with the lock mandrel and safety valve when running the safety valve. For running and setting the lock mandrel and a safety valve, the running tool is shear pinned to the body of the lock mandrel. The safety valve and lock mandrel are driven downwardly into the landing nipple until a no-go ring on the lock mandrel engages a shoulder in the landing nipple. Further downward driving shears the pin between the running tool and the lock mandrel. The running tool is then pulled upwardly expanding the locking keys on the lock mandrel. Pressure is then applied through a control line to the safety valve in the landing nipple relieving the upward force from the safety valve on the running tool prong to release the running tool. The running tool is releasable from the lock mandrel only after the expander sleeve is in the up position and the control line to the safety valve has been pressurized.

The details of a preferred embodiment of the invention together with its objects and advantages will be evident from the following description taken in conjunction with the accompanying drawings wherein:

Figure 1 is a longitudinal view in section and elevation of the lock mandrel of the invention;

Figure 2 is a longitudinal view in section of the key retainer sleeve of the lock mandrel;

Figure 3 is a view in section along the line 3—3 of Figure 2;

Figure 4 is a longitudinal side view in section of one of the locking keys of the lock mandrel of

Figure 1;

Figure 5 is an outside view in elevation of the key of Figure 4;

Figure 6 is an inside view in elevation of the key of Figure 4;

Figure 7 is a bottom end view of the retainer key as seen in Figure 6;

Figures 8A and 8B together form a longitudinal view in section and elevation of the running tool of the invention;

Figure 9 is a view in section along the line 9—9 of Figure 8B;

Figure 10 is a longitudinal view in elevation of the locking dog retainer sleeve of the running tool;

Figure 11 is a longitudinal view in section of the sleeve of Figure 10;

Figure 12 is a view in section of the sleeve as seen along the line 12—12 of Figure 11;

Figure 13 is an outside view in elevation of one of the retainer dogs of the running tool;

Figure 14 is a longitudinal view in section of the dog of Figure 13;

Figure 15 is an inside view in elevation of the retainer dog of Figure 13;

Figure 16 is a bottom end view of the retainer dog as seen in Figure 14;

Figures 17A and 17B together are a longitudinal view in section and elevation of the running tool coupled with the lock mandrel of the invention connected into the upper end of a well safety valve as the safety valve is run into a well bore;

Figures 18A and 18B together form a longitudinal view in section and elevation of the running tool and lock mandrel of the invention coupled into the upper end of a well safety valve showing the valve and lock mandrel and a fragment of a landing nipple in section in which the safety valve and lock mandrel are landed; and

Figures 19A and 19B taken together form a longitudinal view in section and elevation of the running tool, lock mandrel, and upper end portion of the safety valve in a landing nipple shown in fragmentary section in which the lock mandrel locking dogs are expanded into the lock recess of the landing nipple.

Referring to Figure 1, a lock mandrel M includes a tubular body formed by a locking dog retainer sleeve 30 and a packing mandrel 31, radially movable locking dogs 32, a locking dog expander sleeve 33, and a packing assembly 34. The dogs 32 are radially movable in windows 35 provided in the retainer sleeve 30. The expander sleeve 33 moves within the locking dogs between an upper locking position shown in Figure 1 and a lower dog release position.

Referring to Figures 2 and 3, the locking dog retainer sleeve 30 has an internal annular locking recess 40 having an upper end lock surface 41 to receive upper locking keys on the running tool of the invention used to set the lock mandrel and safety valve in a landing nipple. The sleeve 30 has a plurality of circumferentially spaced shear pin holes 41 for securing the lock mandrel to a running tool. The windows 35 in the sleeve 30 are circumferentially spaced, each window being sized and shaped to receive and retain one of the locking dogs 32 with the sleeve allowing the dog to move radially between an inward release position and an outward expanded locking position. The bore of the lower portion of the sleeve 30 extending within the windows 35 is graduated and shaped to accommodate the locking dog expander sleeve 33. A tapered stop shoulder 42 along the sleeve bore limits the upward movement of the expander sleeve 33. As evident in Figures 2 and 3 each of the windows 35 has longitudinal inner side retainer recesses 43 which receive retainer flanges along the side edges of the locking dogs 32 to hold the dogs in the windows of the sleeve 30. The lower end portion of the sleeve 30 is internally threaded at 44 for connection of the sleeve on the upper end of the packing mandrel 31. An external annular no-go ring 45 is formed on the lower end portion of the sleeve 30 to limit the downward movement of the mandrel M in a landing nipple.

The locking dog expander sleeve 33 as illustrated in Figure 1 is a tubular member having upper and lower guide or bearing end portions 50 and 51. The upper end portion 50 of the sleeve 33 slides within the bore of the sleeve 30 above the stop shoulder 42 while the lower guide portion 51 of the sleeve slides within the bore of the packing mandrel 31. The bore of the expander sleeve 33 is graduated having an enlarged lower end portion providing a tapered operating shoulder 52 for engagement by an operating key on the running tool to lift the expander sleeve in moving the locking dogs 32 outwardly to lock positions. The outside diameter of the central portion of the expander sleeve 33 is also graduated providing an upper central portion 53 and a larger lower central portion 54. A tapered cam surface 55 is provided on the expander sleeve on the upper end of the portion 53. A tapered cam surface 60 is provided on the sleeve 33 between the portions 53 and 54. An external annular latch recess 61 is provided on the expander sleeve portion 53 to releasably latch the expander sleeve in the upper lock position.

Each of the locking keys 32 as illustrated in Figures 4—7 is a circular arcuate segment shaped to fit within the windows 35 of the sleeve 30 and having an outer locking profile and an inner profile engageable by the expander sleeve 33 for expanding and locking the keys. The side edges of the locking dogs 32 each has an integral longitudinal retainer flange 62 which fits the retainer recesses 43 along the windows 35 of the sleeve 30 to hold the locking dogs 32 in the windows at the expanded positions as shown in Figure 1 of the dogs. Each of the dogs 32 has an outer locking boss surface 63 shaped to fit within a locking recess of a landing nipple for locking the lock mandrel M in the landing nipple. The inside faces of the dogs 32 as particularly shown in Figures 4 and 5 are graduated surfaces defined by an upper inside face 64 and a lower inside face 65. The lower end of the face 65 has an inside cam surface 70. Between the surfaces 64 and 65

each dog has a sloping cam surface 71. The face 64 also has a latching lip or ridge 72 which is engageable in the latch recess 61 of the sleeve 33 so that when the sleeve is in the upper locked position of Figure 1, the expander sleeve is releasably locked at the upper position at which the dogs 32 are expanded. The cam surfaces 70 and 71 on the inside faces of the dogs 32 cooperate with cam surfaces on the expander sleeve 33 for moving the dogs outwardly to the locked positions as the retainer sleeve 33 is lifted upwardly from a lower release position to the upper end lock position of Figure 1. Additionally for latching the sleeve 33 at the upper end position the sleeve 33 has an external annular latch flange 73 provided around the lower end portion 51 of the sleeve while the packing mandrel bore has an internal annular latch flange or shoulder 74. At the upper locked position of the sleeve 33 the latch flange 73 on the sleeve moves above the latch flange 74 within the bore of the packing mandrel to further aid in holding the expander sleeve 33 at the upper locking position.

Referring to Figures 8A and 8B, the running tool R embodying the features of the invention has a fishing neck 80 provided with standard wireline features for connection in a wireline tool string including a reduced threaded upper end portion 81 and an external annular flange 82. The fishing neck has an enlarged lower end skirt portion 83 which has a bore 84 provided with a reduced internally threaded upper end portion 85. An upper setting sleeve 90 is secured along an externally threaded upper end portion into the threaded bore portion 85 of the fishing neck. The fishing neck skirt 83 and the upper end portion of the sleeve 90 are in concentric spaced relation. The sleeve 90 has a pair of longitudinal slots 91 positioned along opposite sides of the sleeve. The lower end portion of the setting sleeve 90 is counterbored at 92 and provided with a shear pin hole 93 and a set screw hole 94. Above the set screw hole 94, the sleeve 90 has an external annular latch release recess 95. A latch key retainer sleeve 100 is telescoped in sliding relation over the lower end portion of the sleeve 90 into the skirt 83 between the sleeve 90 and the skirt. The sleeve 100 has circumferentially spaced windows 101 shaped to receive and retain a latch key 102. As shown in Figure 12 each of the windows 101 of the sleeve 100 has longitudinal opposite side key retainer lips or flanges 103 defining along each longitudinal side edge of the windows a longitudinal recess 104. As illustrated in Figures 13—16 each of the latch keys 102 is an arcuate circular segment having an outer face 105 and an inner face 110. The outer face has a locking boss 111 provided with a transverse garter spring recess 112 and extending between an upper cam surface 113 and a lower cam surface 114. The locking heads of the keys defined by the outer bosses 111 have inner bosses 115 extending between a sloping cam surface 120 and a sloping cam surface 121. As shown in Figure 16, the longitudinal side edges of the keys 102 are each provided with an inside retainer flange 122 which fit within the window edge recesses 104, Figure 12, and are engageable with the retainer flanges 103 along the window edges of the key retainer sleeve 100 to retain the keys in the windows while permitting the keys to move radially inwardly and outwardly. The keys 102 are fitted within the windows and held by a garter spring 123 which completely encircles the keys and the sleeve 100. The garter spring passes through the outer recess 112 in the latching heads of the keys and between the keys through a segment of the external annular recess 124 formed in the outer surface of the sleeve 100 intersecting the lower ends of the windows 101. The spring binds the keys within the windows while allowing the latch head ends of the keys to move radially between expanded latching positions and retracted release positions. The keys 102 are movable longitudinally with the sleeve 100 between expanded latching positions and contracted release positions. When the latching heads of the keys are aligned with the release 95 of the sleeve 90 the garter spring 123 pulls the latching heads of the keys inwardly to release positions.

Continuing with reference to Figures 8A and 8B, a lower setting sleeve 130 is telescoped along an upper end portion into the counterbore 92 of the upper setting sleeve 90. A set screw 131 through the lower end portion of the sleeve 90 secures the lower setting sleeve with the upper setting sleeve. The lower portion of the lower setting sleeve has a plurality of circumferentially spaced downwardly extending longitudinal collet fingers 132 each having a latch head 133. Each of the collet finger latch heads has an upper outer tapered cam surface 134 for shifting the locking dog expander sleeve 54 in the mandrel M and thereafter for camming the latch heads 133 inwardly to release positions. It will be obvious in Figures 8A and 8B that the collet fingers 132 join the main body of the sleeve 130 at the upper ends of the fingers while the fingers including the latch heads 133 are free to spring inwardly and outwardly for latching and operation of the lock mandrel M. A tubular core 135 is telescoped in sliding relationship into the upper setting sleeve 90 through the lower setting sleeve 130. The core has an external annular release recess 135 which allows the latch heads 133 on the collet fingers 132 to move inwardly to release positions when the latch heads are aligned with the recess 136. When the latch heads are misaligned from the recess 136 and thus are along the larger diameter of the core above the recess, the outer surface of the core holds the latch heads 133 outwardly at operating positions. The upper end portions of the latch key retainer sleeve 100 and the core 135 are secured together by a spiral pin 141 which extends from opposite sides of the sleeve 100 through the longitudinal slots 91 of the upper setting sleeve 90 and the opposite sides of the core 135. The pin 141 secures the key retainer sleeve 100 with the core so that the two members

are rigidly connected together and thus movable as a common unit. Similarly the fishing neck and the upper setting sleeve 90 are secured together moving as a unit relative to the key retainer sleeve 100 and the core 135. When the fishing neck is raised or lowered the upper setting sleeve 90 is correspondingly raised or lowered relative to the key retainer sleeve 100 and the core 135. Movement of the fishing neck 80 moves the upper setting sleeve 90 relative to the key retainer sleeve 100 which holds the upper latch keys 102 and thus the latch key release recess 95 is moved relative to the keys 102. Similarly movement of the fishing neck moves the collet fingers 132 which depend from the sleeve 130 so that the collet heads 133 are moved along the core 135 relative to the release recess 136. The upper latch key heads 111 and the lower latch heads 133 on the collet fingers 132 function to connect the running tool R with the lock mandrel M, operate the lock mandrel M, and release the running tool from the lock mandrel at the different relative positions of the upper and lower setting sleeve, the upper latch keys, and the collet fingers on the lower setting sleeve.

The lock mandrel M and the running tool R are useful for running and setting standard remote controlled wireline tubing safety valves in no-go type nipples. A typical safety valve with which the lock mandrel tool is operable is an Otis type DK tubing safety valve illustrated at page 3998 of the 1974—75 edition of the *Composite Catalog of Oilfield Equipment and Services* published by World Oil, Houston, Texas and an Otis type RQL no-go safety-valve nipple shown at page 4004 of the same catalog. In operation with the DK Otis safety valve, the lock mandrel M of the present invention is substituted for the locking mandrel illustrated at page 3998 of such catalog.

In preparation for operating the lock mandrel M and the running tool R of the invention, the lock mandrel is secured with a safety valve S as illustrated in Figure 17B by threading the lower end of the lock mandrel packing mandrel 31 into the internally threaded upper end portion of the housing 150 of the safety valve. The operating fluid system of the safety valve, not shown, is connected to a suitable source of control fluid pressure which is used to pump the safety valve to the open position at which the operating tube 151 of the safety valve is at a lower end position as illustrated in Figure 17B. The operating tube 151 is connected with a fluid responsive piston and a spring, not shown, permitting remote control of the valve from the surface after it is installed. In downhole operation the valve is held open by fluid pressure applied from the surface and when the pressure is released the spring closes the valve. When the valve is pumped open the spring is compressed applying an upward force on the operating tube.

With the safety valve pumped open, the running tool R is extended to maximum length by sliding the fishing neck 80 toward the sleeve 100. The running tool is then inserted into the connected lock mandrel M and safety valve S. As the running tool is inserted the collet fingers 132 move along the lock mandrel until the fingers pass into the expander sleeve 33 past the internal cam surface 52 with the collet heads 33 springing outwardly into the larger bore of the sleeve 33 below the cam surface 52. The heads 111 on the latch keys 102 engage the upper end of the retainer sleeve 30 moving into the bore of the sleeve below the internal tapered shoulder 41 into the bore portion 40 of the sleeve. The core 135 extends downwardly through the lock mandrel into the upper end of the safety valve. The fluid pressure holding the safety valve open is then released so that the spring engaged with the operating tube 151 of the safety valve urges the operating tube upwardly against the tapered end edge surface 138 on the prong 137 secured on the lower end of the core. The upward force of the safety valve spring lifting the core applies an upward force to the pin 141 which urges the key retainer sleeve 100 upwardly. The upward force on the sleeve 100 urges the upper latch keys 102 upwardly along the outer surface of the sleeve 90 above the release recess 95 in the sleeve so that the heads 111 of the key are trapped or captured within the annulus between the bore 40 of the sleeve 30 around the sleeve 90 between the internal annular tapered surface 41 within the sleeve 30 and the lower tapered end edge surfaces 101a of the windows 101 in the key retainer sleeve 100. The upward force on the sleeve 100 is applied from the window surfaces 101a to the inside end surfaces 121 of the latch key heads 111 urging the latch keys upward and outwardly so that the upper outer surfaces 113 on the latch key heads are urged against the internal annular tapered surface 41 within the lock mandrel sleeve 30 locking the running tool with the sleeve 30. At the lower end of the running tool the collet heads 133 are held at normal positions by the outer surface of the core below the core recess 136 so that the surfaces 134 on the collet heads 133 are engageable with the cam surface 52 within the lock mandrel expander sleeve 33. The running tool is manipulated by pulling the fishing neck 80 away from the lock mandrel slightly until the shear pin holes 41 in the lock mandrel sleeve 30 line up with the shear pin holes 93 in the running tool sleeve 90. Shear pins are then inserted through the holes 41 of the lock mandrel into the holes 93 of the running tool pinning the lock mandrel on the running tool. Figures 17A and 17B illustrate the safety valve and lock mandrel connected on the running tool for running and setting the safety valve. It will be seen that the upper keys 102 of the running tool are engaged in the sleeve 30 of the lock mandrel M, the collet finger heads 133 are engaged in the expander sleeve 33 of the lock mandrel, and the expander sleeve 33 is at the lower end position at which the locking dogs 32 on the lock mandrel are at inwardly release positions. The lock mandrel and safety valve are then in condition for running into a well bore and setting in a landing nipple.

The running tool R is connected at the fishing neck 80 with a wireline tool string, not shown, used to lower the running tool, lock mandrel, and safety valve through a flow conductor in a well bore, not shown, into a landing nipple 160 as represented in Figure 18B. The landing nipple is provided with an internal annular locking recess 161 and a no-go stop shoulder 162. The safety valve and lock mandrel are driven downwardly using jars in the wireline tool string until the integral no-go ring 45 on the lower end of the lock mandrel sleeve 30 engages the no-go shoulder 62 in the landing nipple. The seal assembly 34 moves downwardly along the seal surface 163 of the landing nipple below the shoulder 162. Further downward jarring applying downward forces to the fishing neck 80 drives the fishing neck downwardly until the lower end edge of the skirt 83 on the fishing neck engages the upper end edge of the mandrel sleeve 30 shearing the pins 155 connecting the running tool with the mandrel skirt. Figures 18A and 18B illustrate the safety valve and lock mandrel landed in the landing nipple on the no-go shoulder and the running tool manipulated to shear the pins 155 connecting between the running tool and the lock mandrel sleeve 30. The running tool remains coupled into the lock mandrel by means of the upper keys 102 and the collet fingers 132. The spring in the safety valve continues to exert upward force on the probe 137 and core 135 which is applied through the pin 141 to the upper setting sleeve 100 applying the upward and outward force from the sleeve window edges 101a to keep the retainer keys 102 tightly expanded in locking relation in the lock mandrel sleeve 30 against the shoulder 41 of the sleeve. Upward force is applied on the line, not shown, to the wireline tool string. A bind on the line greater then the weight of the tools in the string indicate that the safety valve S is in position in the landing nipple. The fishing neck 80 is jarred upwardly pulling the upper setting sleeve 90 and the lower setting sleeve 130 upwardly raising the collet fingers 132 between the core 135 and the key retainer sleeve 100 which remain held against upward movement due to the locking action of the upper retainer keys 102. As the collet fingers 132 are lifted the upper edge surfaces 134 on the collet heads 133 engage the tapered shoulder 52 within the lock mandrel expander sleeve 33 lifting the sleeve 33 within the locking dogs 32. As the sleeve 33 moves upwardly the cam surfaces 55 and 60 on the sleeve engage the internal cam surfaces 70 and 71 respectively in the locking dogs camming the dogs radially outwardly to fully expanded positions as illustrated in Figures 19A and 19B and in Figure 1. The locking dogs 32 move outwardly until the outer bosses on the dogs engage the landing nipple locking recess 161 locking the lock mandrel M along with the safety valve S against longitudinal movement within the landing nipple. The lock mandrel expander sleeve 33 moves to an upper end position at which the cam surface 55 on the sleeve 33 engages the stop shoulder 42 within the sleeve 30 of the mandrel M. At the upper position of the sleeve 33 within the dogs 32 the dogs are firmly held in the radially expanded positions illustrated in Figures 19A and 19B and in Figure 1. An upward force or bind is then applied to the line supporting the wireline tool string and fluid pressure is applied to the control line leading to the safety valve S. The control line pressure in the safety valve chamber against the piston on the safety valve operator tube 151 moves the safety valve operator tube slightly downwardly relieving the upward force of the spring in the safety valve on the operator tube which has been urging the tube against the running tool core holding the running tool locked in the lock mandrel by means of the upper retainer keys 102. The upward bind on the wireline then lifts the fishing neck 80 pulling the upper setting sleeve 90 and the lower setting sleeve 130 upwardly relative to the key retainer sleeve 100 and the core 135 of the running tool. The upward movement of the sleeves 90 and 130 raises the release recess 95 of the sleeve 90 into alignment behind the retainer key heads 111 and raises the collet finger heads 133 camming the heads into the recess 136 on the core. When the release recess 95 is aligned with the retainer key heads 111, the garter spring 123 squeezes the retainer keys 102 inwardly retracting the key heads 111 from engagement with the shoulder 41 at the upper end of the bore portion 40 in the lock mandrel sleeve 30 releasing the running tool from the lock mandrel. As the running tool is pulled upwardly the cam shoulder 52 within the lock mandrel sleeve 33 acts on the upwardly moving cam edges 134 on the collet finger heads 133. The collet finger heads 133 are squeezed inwardly into the recess 136 of the core releasing the collet finger heads from the lock mandrel expander sleeve. The frictional engagement of the packing assembly 34 on the lock mandrel M in the seal surface of the landing nipple below the no-go shoulder 162 restrains the lock mandrel from pulling out of the landing nipple while the lock mandrel is manipulated by the running tool for locking the mandrel in the landing nipple. If the lock mandrel does not properly release from the running tool, the mandrel and safety valve will be pulled back upwardly when the running tool is lifted. For example if the control pressure is not properly applied to the safety valve, the upward force on the probe surface 138 will not be relieved so that the upper latch keys 102 will not release from the lock mandrel sleeve surface 41. Similarly if the locking dogs 32 are not expanded into locking relation in the landing nipple locking recess 161 the expander sleeve 33 cannot be pulled upwardly thereby restraining the collet finger heads 133 which cannot be pulled upwardly along the core to align with the release recess 136 and therefore the running tool will be restrained in the lock mandrel at the collet fingers 132. In the event that such malfunctions occur allowing the running tool with the lock mandrel and the safety valve to be pulled upwardly from the landing nipple, the running tool, lock mandrel,

and safety valve are forced back downwardly into the landing nipple repeating the required steps for setting the lock mandrel in the landing nipple and releasing the running tool. After proper release of the running tool from the lock mandrel, the lock mandrel is left releasably locked in the landing nipple and the safety valve is under the control of the control pressure operated from the surface for opening and closing the safety valve as required by operating conditions of the well. The expander sleeve 33 of the lock mandrel M is restrained against accidental release by engagement of the latch flanges 72 within the dogs 32 in the latch recess 61 of the sleeve and by the latch boss 71 along the lower end portion of the sleeve being positioned above the internal annular latch flange 74 within the packing mandrel 31 of the lock mandrel.

It will be recognized that the apparatus of the invention comprising the lock mandrel M and the running tool R provides well tool structure adapted to running and setting in a no-go type landing nipple by application of a downward force and releasably locking of the lock mandrel M to hold the safety valve in place in a well bore by application of a reverse upward direction force. Accidental release and possible inadvertent locking or other malfunction during the driving of the lock mandrel downwardly into position in a landing nipple is avoided.

The lock mandrel M with the safety valve S is removable from the landing nipple by the use of an Otis conventional GR or Gs pulling tool as illustrated at pages 3988—3989 of the 1974—75 "Composite Catalog of Oilfield Equipment and Services", supra. Such pulling tool is equipped with a prong connected with the pulling tool core for engaging and releasing the lock mandrel expander sleeve 33 by pushing the sleeve downwardly and for engaging the operating tube 151 of the safety valve S to hold the valve open while the mandrel and valve are being pulled.

A fail-safe feature of the running tool will permit release of the mandrel dogs 32 for pulling the running tool, mandrel M, and safety valve back out of a well. The set screw or screws 131 are selected to shear for releasing the lower setting sleeve 130 from the upper setting sleeve 90. If there is a malfunction, for example, in control fluid pressure to the safety valve after the mandrel is locked, an upward pull on the head 80 will shear the screws 131. The head is then driven downwardly which forces the upper setting sleeve downwardly against the lower setting sleeve and against the expander sleeve 33 which is forced down to a lower end position from behind the dogs 32 releasing the dogs to move inwardly. The head 80 is then pulled upwardly, but since the lower setting sleeve 130 has been released from the upper sleeve 90, the collet fingers 132 are not pulled up in the expander sleeve 33, and thus the expander sleeve is not moved behind the dogs 32 which remain released as the pulling tool, mandrel, and safety valve are pulled. The mandrel can therefore be pulled without resetting the locking dogs.

CLAIMS

1. A lock mandrel for releasably locking a well tool in a landing nipple along a wire bore, comprising a body having side windows, an annular seal assembly around said body for sealing between said body and a seal surface in said landing nipple, support shoulder means on said body for supporting said mandrel in a no-go landing nipple, a radially movable locking dog in each of said side windows, an expander sleeve in said body slidable within said locking dogs for expanding and releasing said locking dogs, and means for connecting said mandrel body to said well tool to support said well tool from said lock mandrel.

2. A lock mandrel according to Claim 1, wherein the expander sleeve is movable in a direction opposite to the direction of movement of the lock mandrel into the landing nipple to expand the locking dogs.

3. A lock mandrel according to Claim 1 or 2, wherein said lock mandrel body has an internal annular recess for engagement of said latch keys and said expander sleeve has an internal annular recess for engagement by said collet fingers on the well tool.

4. A lock mandrel according to Claim 1, 2 or 3, including latch means for releasably latching said expander sleeve at a position at which said locking dogs are expanded.

5. A lock mandrel according to Claim 4, wherein said latch means comprises a latch recess around said expander sleeve and latch lips within said locking dogs for engagement with said latch recess, a latch flange around said expanded sleeve, and a latch flange within said mandrel body.

6. A lock mandrel according to any preceding claim, wherein said support shoulder on said mandrel body comprises an annular no-go ring between said locking dogs and said seal assembly.

7. A lock mandrel according to any preceding claim, wherein said locking dogs are each provided with internal cam surfaces for expanding said dogs and said expander sleeve is provided with external cam surfaces for engaging said locking dog cam surfaces.

8. A lock mandrel for releasably locking a well tool in a landing nipple along a well bore, substantially as described with reference to, or as shown in, the drawings.

9. An assembly for setting and locking a well tool in a landing nipple along a well bore, comprising a lock mandrel as defined in any of Claims 1 to 8, and a running tool having a head assembly for connection with an operating tool string, an upper latch key assembly connected with said head assembly for coupling said running tool with said mandrel body, a lower collet having a finger assembly for coupling said running tool with said lock mandrel expander sleeve, and a core having a prong end coupled with said head

assembly for engaging a well tool operating member to apply a force from said operator member to said latch key assembly to lock said key assembly with said mandrel body, said head assembly and core being movable in a direction opposite to the direction of setting said assembly in said landing nipple to expand said lock mandrel locking dogs and release said running tool from said lock mandrel.

10. An assembly according to Claim 9, wherein said lower collet is movable along said core and said core has an external annular release recess for releasing said collet from said lock mandrel expander sleeve when said recess is aligned with said collet fingers.

11. An assembly according to Claim 10, including an upper setting sleeve connected between said head assembly and said lower collet for moving said lower collet along said core, said upper setting sleeve having an external annular release recess alignable with said upper latch key assembly for releasing said upper latch key assembly simultaneously with release of said lower collet.

12. An assembly according to any of Claims 9 to 11, wherein said latch key assembly and said core are pinned together and movable as a unit relative to said head assembly for operating said lock mandrel expander sleeve and releasing said running tool from said lock mandrel.

13. An assembly according to any of Claims 9 to 12, wherein said upper latch key assembly includes a key retainer sleeve pinned to said core and said retainer sleeve includes a tapered cam surface engageable with cam surfaces on said latch key assembly for urging said latch key assembly into locking relationship with said lock mandrel body responsive to a force applied to said core from a well tool coupled with said locking mandrel.

14. A running tool for setting and locking a lock mandrel in a landing nipple along a well bore, comprising a head assembly for connection of said running tool with an operating tool string, an upper latch key assembly for coupling said running tool with the body of said lock mandrel, a lower collet assembly supported from said head assembly for coupling with an expander sleeve in said lock mandrel, and a core having a prong end connected with said upper latch key assembly for engagement with an operating member of said well tool to apply a force from said well tool to said upper latch key assembly for holding said key assembly in locked relation with said lock mandrel body, said core having collet lock and release means movable relative to said lower collet to operate said lower collet in response to movement of said head assembly for moving said lock mandrel expander sleeve and releasing said running tool from said lock mandrel.

15. A running tool according to Claim 14, wherein said upper latch key assembly includes a key retainer sleeve having windows therein and a plurality of radially movable latch keys in said windows, pin means between said key retainer sleeve and said core for holding said retainer sleeve and said core together as a unit when said head assembly is moved to shift said expander sleeve in said lock mandrel for expanding locking dogs of said lock mandrel and thereafter for releasing said running tool from said lock mandrel.

16. A running tool according to Claim 14 or 15, wherein said lower collet assembly is secured through shear pin means with said head assembly for fail-safe removal of said running tool and lock mandrel from a well bore.

17. A running tool for setting and locking a lock mandrel in a landing nipple along a well bore, substantially as described herein with reference to, or as shown in, the drawings.

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